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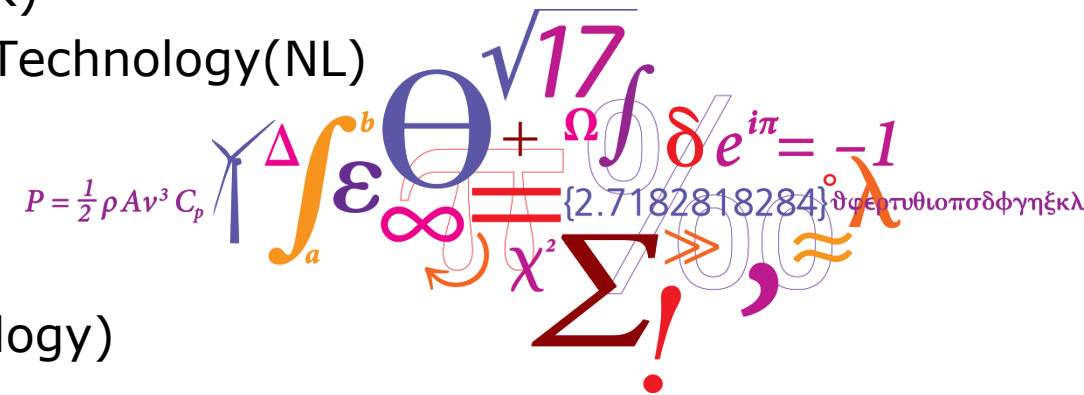
Potential of MgB_2 superconductors on direct drive generators for wind turbines

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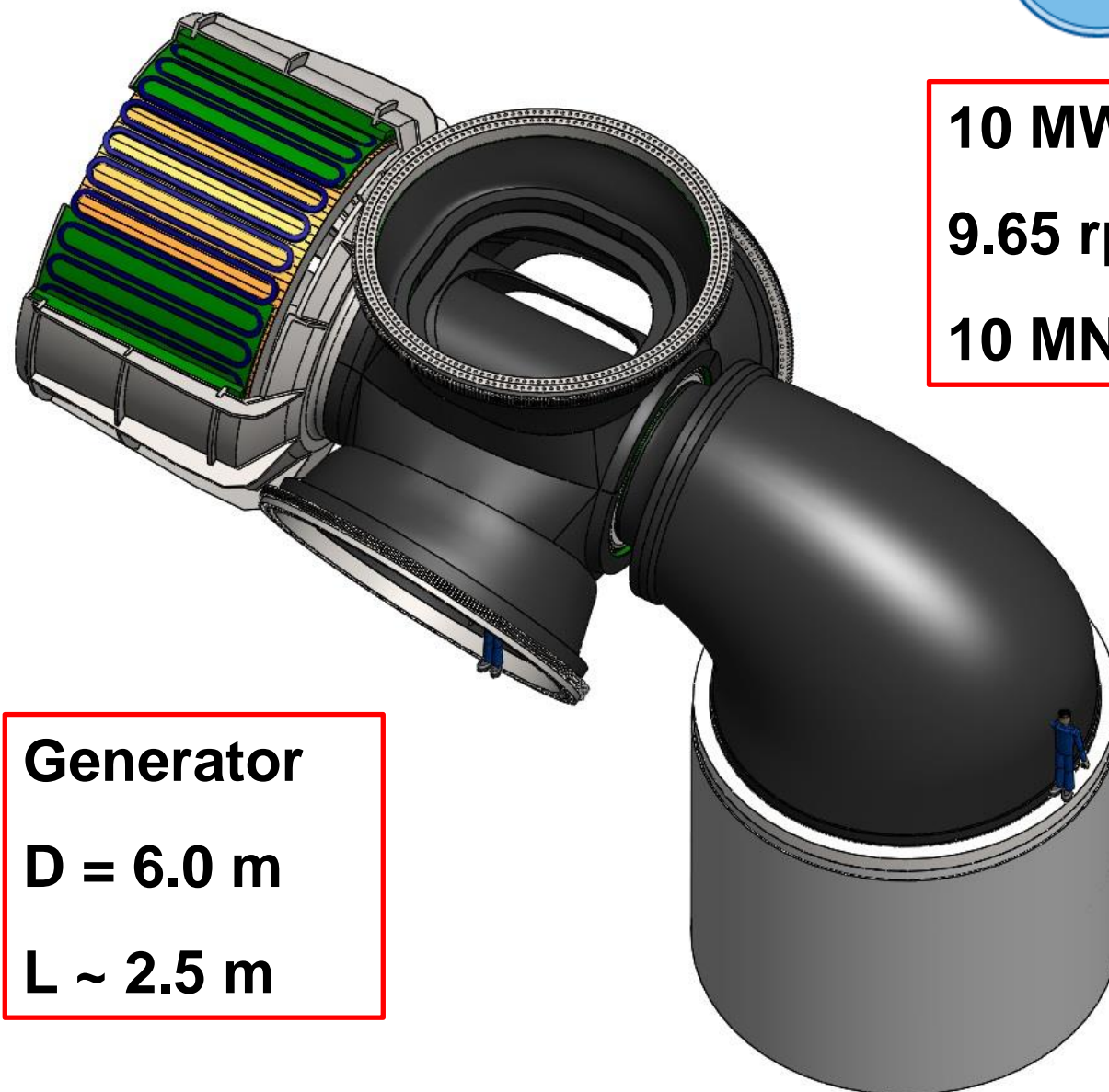
Innovation in wind turbine drive trains (Turbine technology)

Thursday 19 November 2015 14:30-16:00

EWEA 2015, Paris

Outline

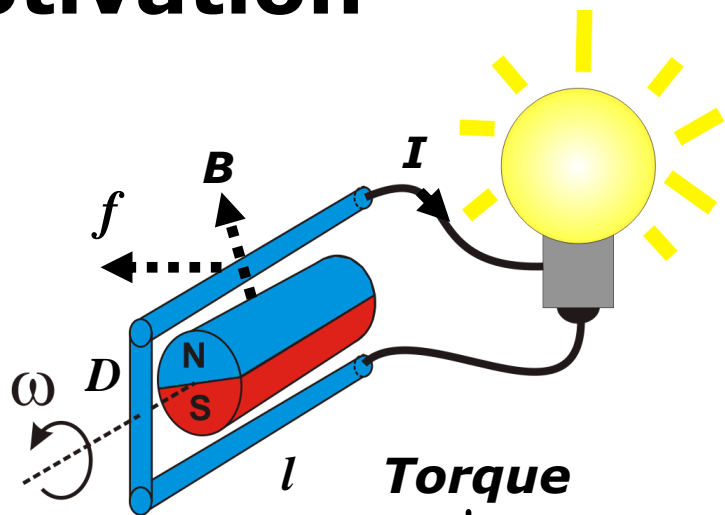
- Motivation
- Design philosophy
- Generator optimization
- Active material cost
- Road map for 10 GW
- Conclusion



10 MW
9.65 rpm
10 MNm

Generator
D = 6.0 m
L ~ 2.5 m

Motivation



$$\text{Power} \propto B I D^2 l \omega$$

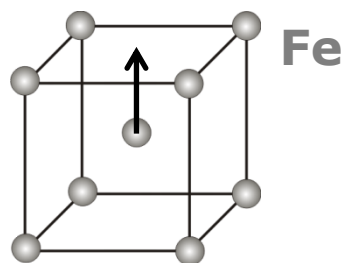
1G : Copper coils + Iron

2G : $R_2Fe_{14}B$ magnets + Fe

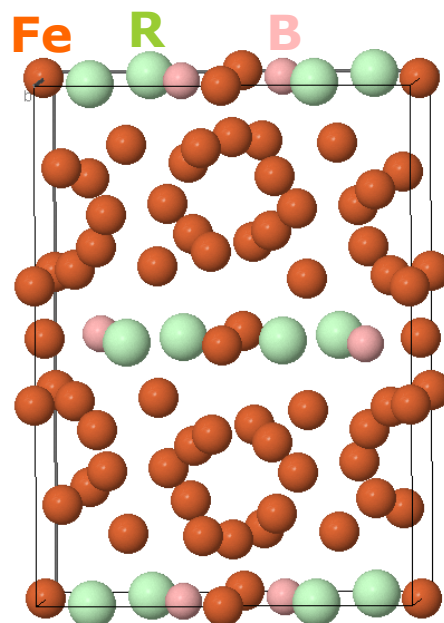
10 MW ~ 6 tons PM

3G : MgB_2 coils + Fe

10 MW ~ No Rare Earth

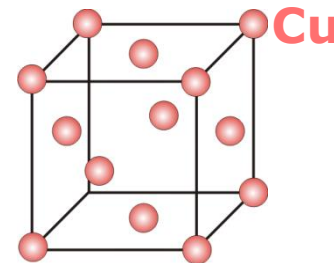


$T_C = 770\text{ }^\circ\text{C}$

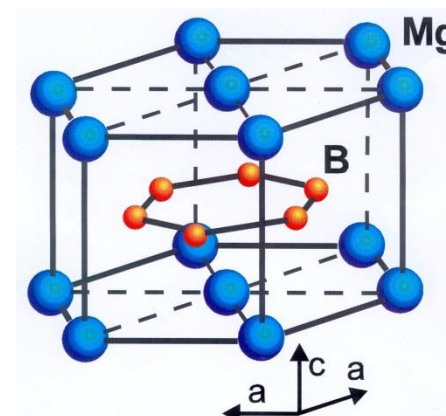


$T_C = 310\text{ }^\circ\text{C}$

$B_r \sim 1.4\text{ T}$



$J \sim 2\text{ A/mm}^2$



$T_C = -234\text{ }^\circ\text{C}$

$B_{c2} \sim 40\text{ Tesla}$

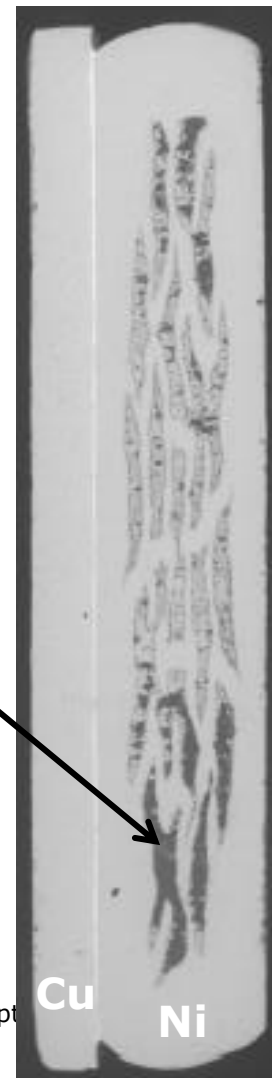
$J < 10000\text{ A/mm}^2$



Columbus wire

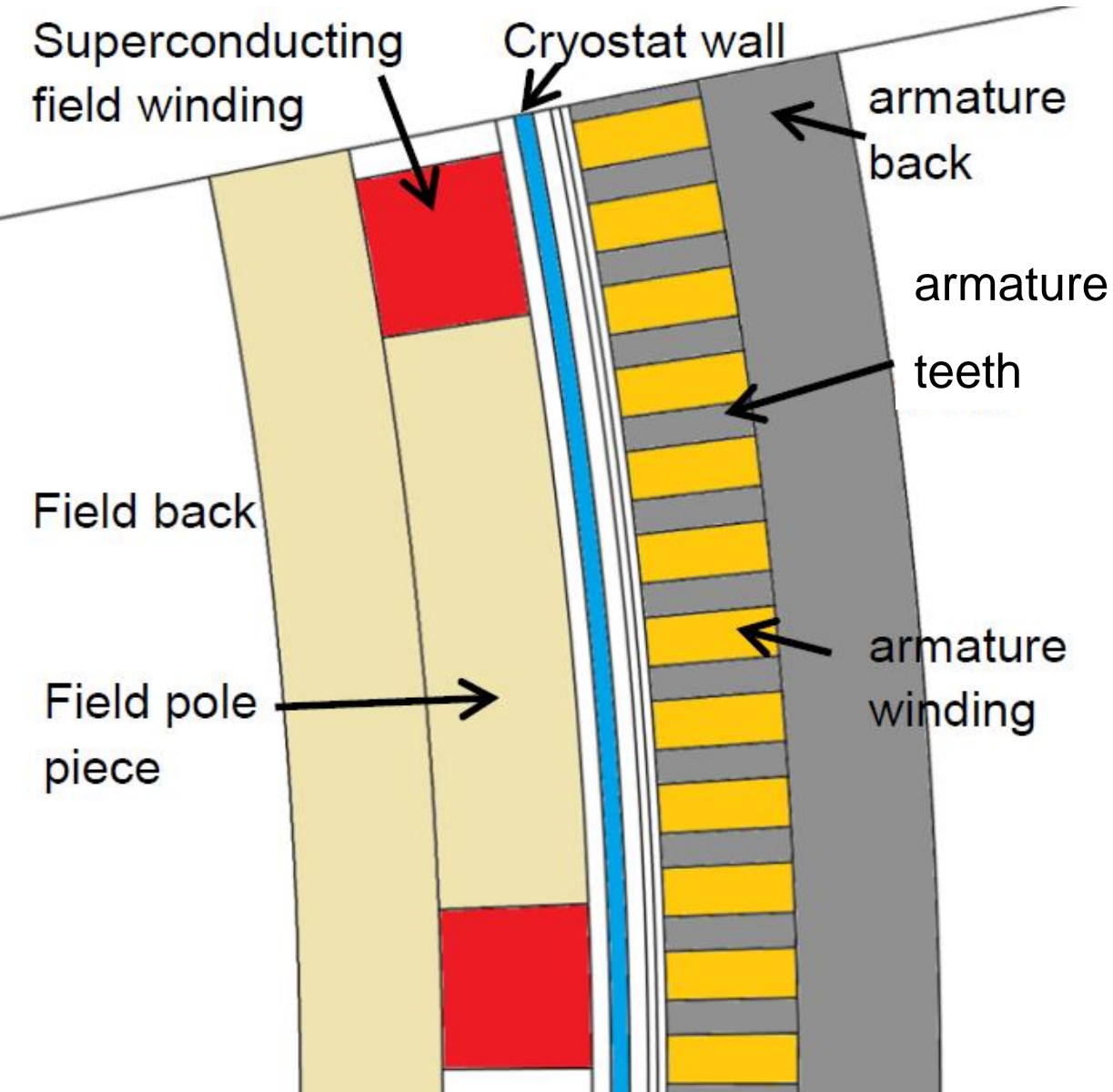
0.7 mm

3.0 mm



20 Sept

Best topology for MgB_2 wires in WTG?

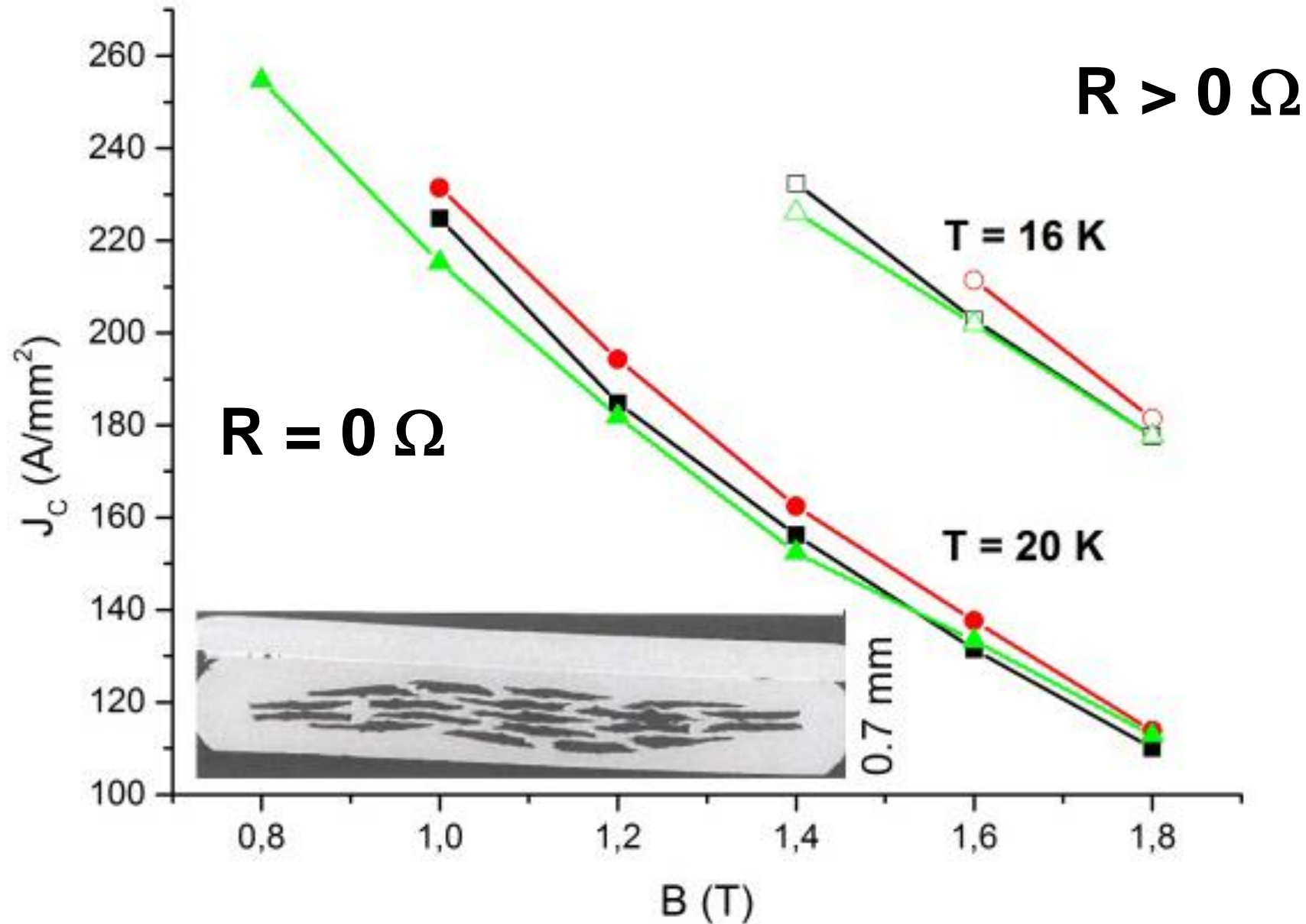


Design philosophy:

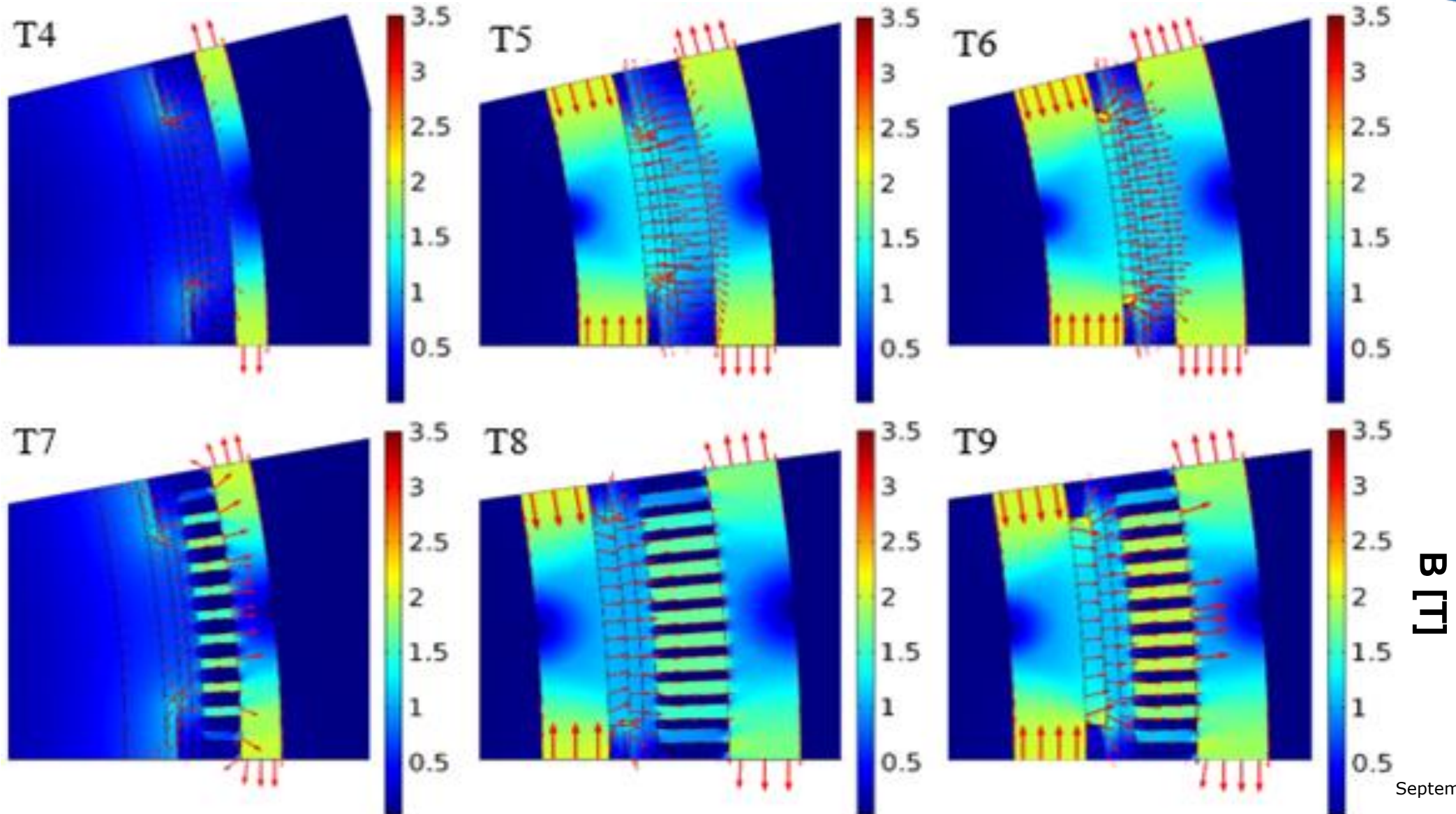
Put as much iron as possible to minimize magnetic flux path

MgB_2:	4 €/m
Fe:	3 €/kg
Cu:	15 €/kg
G10:	15 €/kg
PM:	50-75 €/kg

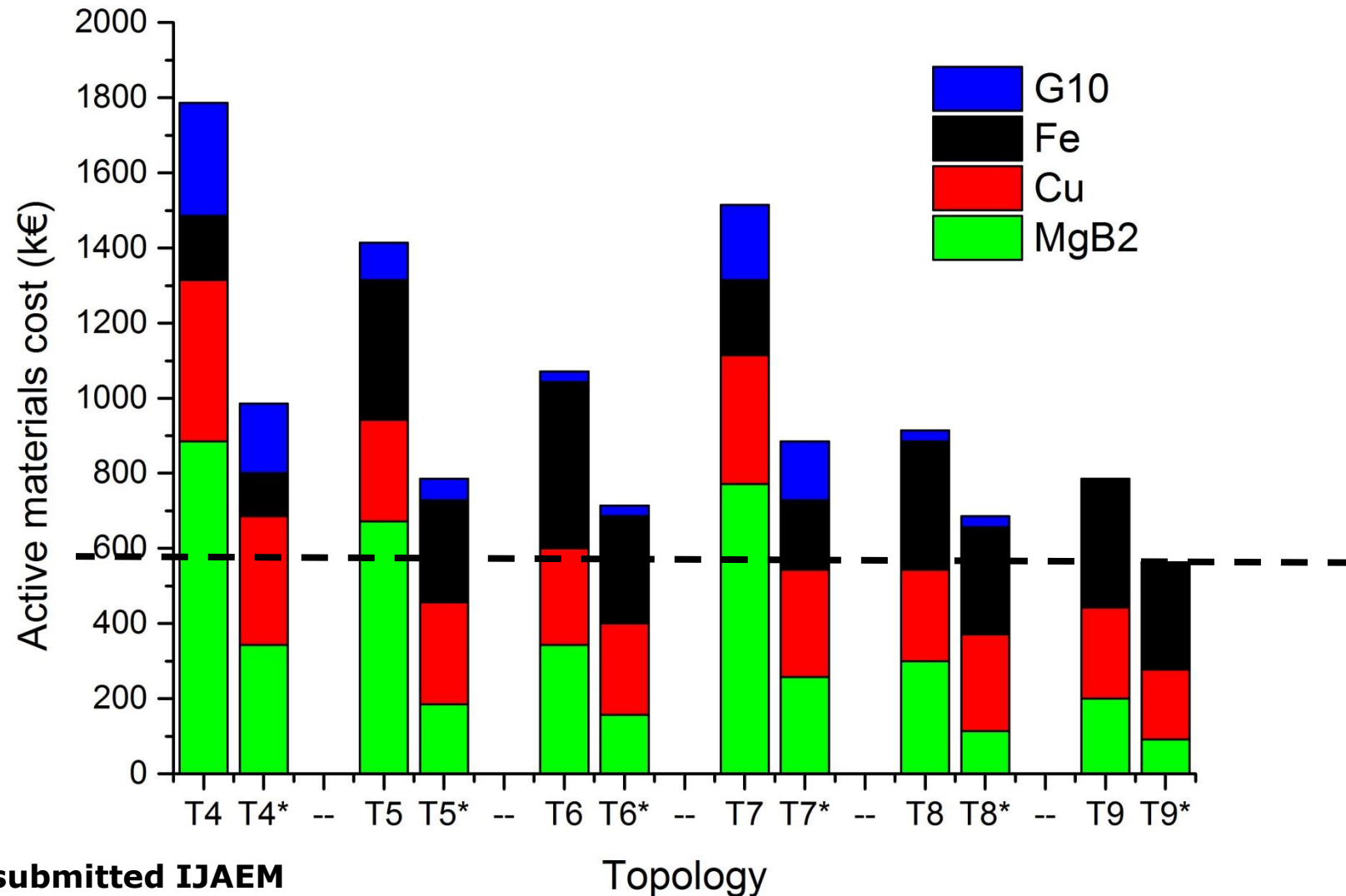
Generator optimization: Operation point



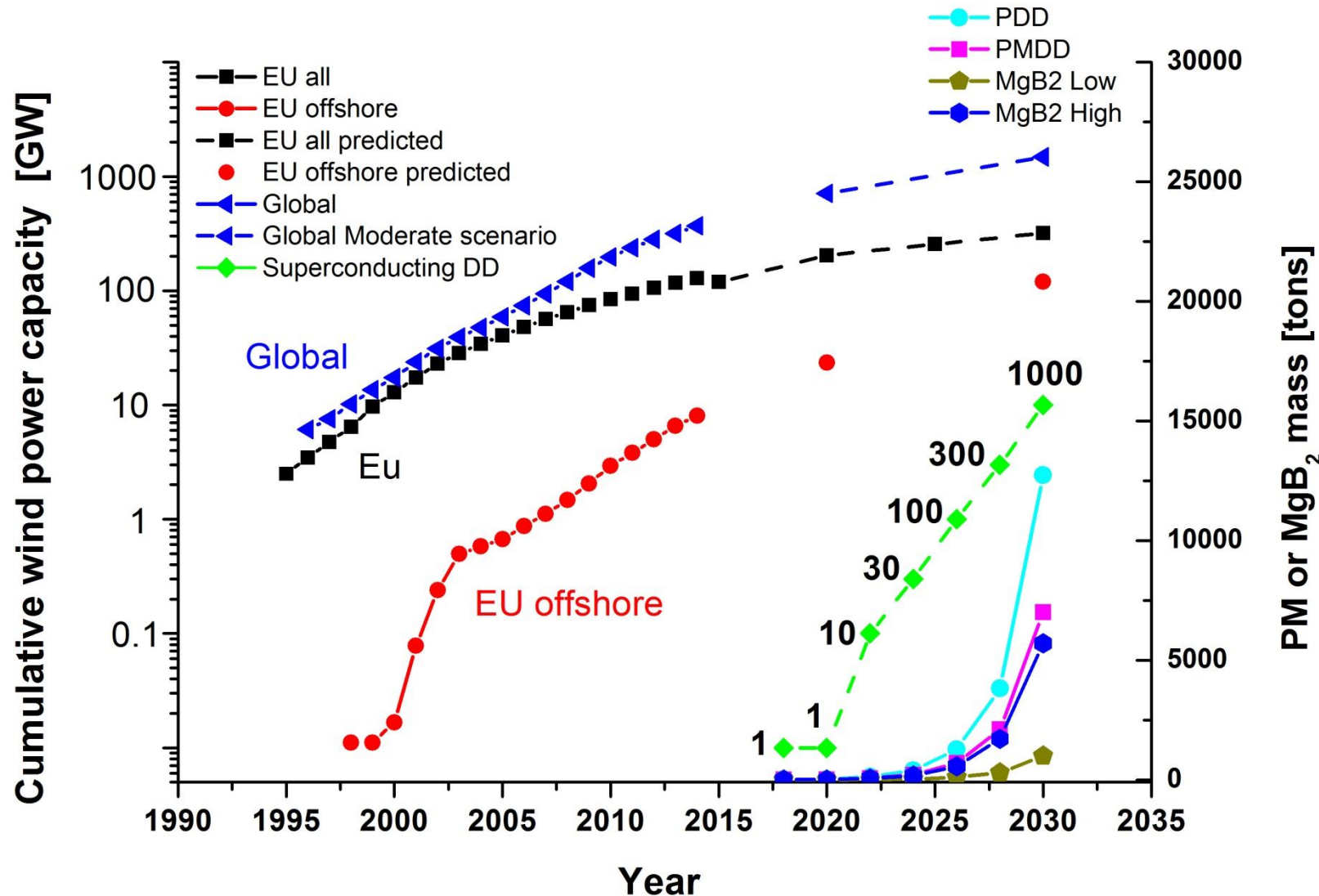
10 MW generator optimization $D = 6.0$ m



Active material cost: MgB_2 4 €/m \rightarrow 1 €/m



Roadmap to 10 GW SCDD



Wire use 10 MW(GW) MgB₂Gen

100 km (Mm)

5000 km/year ↑

$f_{\text{CAPEX}} \sim 1-2\%$

$T = 10-20 \text{ K}$



First attempt to include cryogenic cooling resulted in an INNWIND.EU Levelized Cost of Energy change of a jacket mounted 10 MW turbine in 50 m of water of:

$$\Delta LCoE \sim -0.4\%$$

MgB₂ field coil demonstration – scaled 10 MW

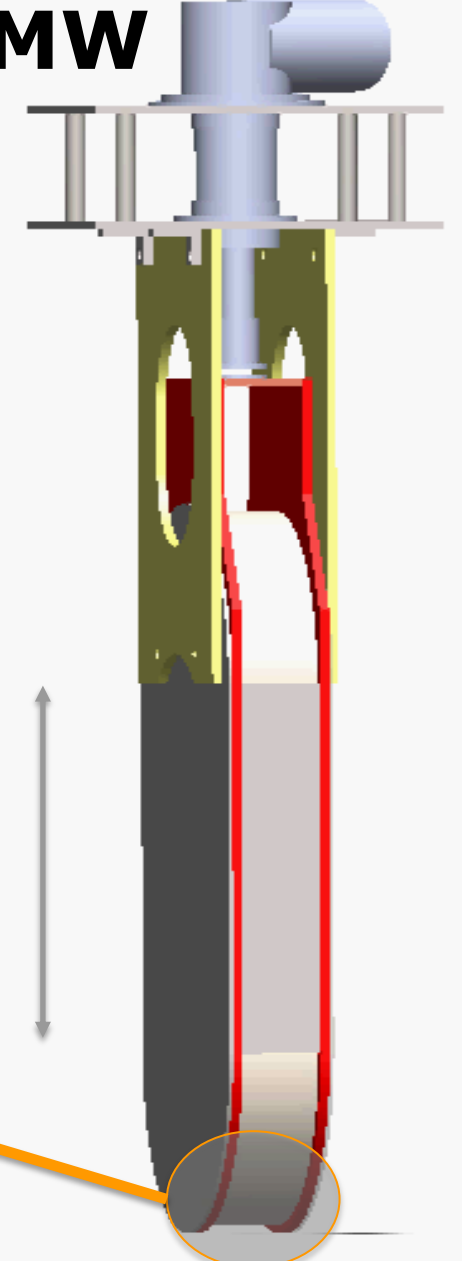
- Tape Columbus Superconductors (5.5 km)
- Kapton insulation & wet winding in Stycast
- 10 double pan-cake coils of 2 x 100 turns
- Cooling to $T = 10\text{-}20\text{ K}$ using cryocooler
- $B_{\text{end,max}} \sim 2.8\text{ T}$ & $B_{\text{center}} \sim 1\text{ T}$

0.7 mm



3.0 mm

0.5 m



Conclusion

- **MgB₂ Direct Drive as alternative to Permanent Magnet Direct Drive**
- **No dependence on Rare Earth Elements (Nd, Pr, Dy) for R₂Fe₁₄B magnets**
- **Philosophy: “Put as much iron as possible into generator”**
 - **Active material cost (SC, PM, Fe, Cu) very similar to PMDD**
 - **First INNWIND.EU turbine + foundation estimate $\Delta LCoE \sim - 0.4 \%$**
- **MgB₂ wire supply chain basically ready for 10 GW MgB₂ SCDD by 2030**
- **Demonstrate MgB₂ field coil technologies → Reliability & Availability ?**

INNWIND.EU Collaborators in Workpackage 3 on Electromechanical Conversion



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 - Delft University of Technology (NL)
- **Niklas Magnuson**
 - SINTEF (N)
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 - DNV GL (NL)
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 - Siemens Wind Power (DK)

Project website: www.innwind.eu

